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Breeding for the Heat Resistant Rhododendrons III. The Feature of Seedling Growth of *R. pseudochrysanthum*, *R. simiarum* and Some of Their Hybrids

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Introduction

In 24 seedlings of *Rhododendron pseudochrysanthum* and their natural hybrids with *R. morii* collected in Hehuan-shan in the preliminary survey of Taiwan in 1983, it was found that this tiny population did contain some seedlings which could tolerate our severe experimental conditions fixed to select the heat resistant rhododendrons. Both species are of the alpine origin of Taiwan usually over 2800 m in altitude and have been considered to be not so heat tolerant. Therefore, this observation was contrary to the long-accepted opinion.

One of the authors (KA) considered this unexpected situation to be the reflection of the fact that, in the long evolutionary process, these alpine species of Taiwan have consistently preserved the heat resistant gene or genes within the whole set of their genes, to have secured its existence as a species against the adverse circumstances which these species had experienced in the past and would do so in the future as well.

The oversea research of 1985[1)] was thus planned and conducted to collect the seeds of *R. pseudochrysanthum* and *R. morii*. In this research the seeds of *R. simiarum* were also collected in Hong Kong. The survival ratio and the feature of seedling growth of these species and some of their hybrids were examined, along with those of some species of Japanese origin, in order to evaluate the value as the gene sources for the breeding of heat resistant rhododendrons.

Materials and Methods

The seeds were collected in Taiwan at the two survey areas, Hehuan-shan and Xitou-shan[1)]. They are located *ca.* 80 km north and *ca.* 20 km south from Yushan (Mt. Morrison), respectively. In Hehuan-shan the collection was conducted at the summit of Hehuan-dongfeng (3416 m), a survey point E (3145 m) tentatively named and the summit of Shimen-shan (3236 m). Based on their habitats and their various characteristics these three populations were determined to be *R. pseudochrysanthum*, *R. morii* and their natural hybrids, respectively. The population of the

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summit of Xitou-shan (3235 m) was *R. pseudochrysanthum*. The seeds of *R. simiarum* were collected in the three survey points (460, 535 and 550 m in altitude) of Ngau-ngak-shan of Maon-shan in Hong Kong[1].

For the comparison of the survival ratio and the feature of seedling growth, the seeds of the species of Japanese origin and those of artificial crosses were also included. As compared with the seeds of Taiwan and Hong Kong collected separately from different individual mother plant, those of Japanese species examined were the mixed seeds in each habitat. The artificial crosses were mainly done by one of the authors (KA), excepting a few seed lots offered by courtesy of some members of Japanese Rhododendron Society.

The pollens of Taiwan origin, KHD1, KHD2 and KHD3, used in hybridization, were obtained from the scions with flower buds collected in Hehuan-shan in late March of 1985 by Mr. Kei-ichiro Ueno. Of these rhododendrons, KHD1 was assumed to be a natural hybrid derivative between *R. pseudochrysanthum* and *R. morii,* and the latter two were regarded as true *R. pseudochrysanthum* from their various characteristics.

The seeds were sown in December, 1985, and the seedlings obtained were transplanted from late March to early April, 1986, to polystyrene boxes (inner size, 56×32×10 cm) filled with the mixtures of pumice, weathered pumice and red clay, 3:1:1 by volumes. They were grown in a plastic house covered with a sheet of black cheese cloth and were kept in a temperature as high as possible by limited ventilation. The liquid fertilizer containing N, P and K, every 100 ppm, was given twice a week throughout the growing season in 1986, which was much severer condition than the previous experiment[2], to facilitate the selection of stronger rooted seedlings against fertilizer and high humid soil condition.

The features of seedling growth, *i. e.*, survival ratio, vigour, plant height and leaf size (width×length) were measured *ca.* every 7 weeks, but as for plant survival, plant height and leaf

Table 1. The mean maximum and minimum temperatures in a growing house in the summer-half of 1986

Month		Maximum temperature (°C)	Minimum temperature (°C)
May	E	30.1	16.0
	M	30.6	14.7
	L	34.2	14.4
June	E	32.2	16.8
	M	30.2	18.9
	L	34.7	22.7
July	E	36.1	23.4
	M	36.6	25.2
	L	38.9	25.3
August	E	39.2	23.2
	M	38.3	24.3
	L	35.2	24.7
September	E	36.2	23.3
	M	31.7	22.8
	L	31.9	18.6
October	E	28.4	15.5
	M	27.5	11.4
	L	24.7	12.3

size, the final data of early December, 1986 and concerning vigour the data of middle October, 1986, were summarized and presented in Figs. 1 and 2. In these figures each corner of square was survival ratio (left), vigour (top), plant height (right) and leaf size (width×length, bottom), respectively. The survival ratio was the percentage of the finally survived individuals to those at the start of measurement in late May, when the seedlings transplanted seemed to have fully been established. The number of seedlings per experimental plot was various, but in the present paper the plots with more than 30 seedlings at the start of measurement were dealt, excepting certain plots in *R. simiarum*, *R. aureum* and *R. pseudochrysanthum* of Xitou-shan, where sufficient seeds could not be obtained. The maximum number of seedlings was 356. The degree of vigour was based on the five grades of visual estimation. Except certain plots with fewer seedlings in which the measurement was done on all individuals, the plant height was measured on the largest 30 individuals selected within each seedling group and the leaf size was based on the measurement of length and width of the largest leaf in each individual of these 30 plantlets selected. In Figs. 1 and 2, both measurements were presented on the percentage basis to the largest seedling group, *i. e.*, in the plant height, the percentage to the value of *R. formosanum*×*R. pseudochrysanthum* KHD2 and in the leaf size, to the value of (Red No. 1×Jock)×*R. simiarum*. The mean maximum and minimum temperatures in a growing house in the summer-half of 1986 were presented in Table 1.

Results and Discussion

(1) Survival ratio

The results obtained were presented in Fig. 1 (1)–(4) for rhododendrons collected in the wild, and in Fig. 2 for those derived from the artificial crosses. The order of arrangement in all of these figures was based on the survival ratio from the highest to the lowest. In Table 2 was noted the summarized survival ratio of species rhododendrons.

As seen in Table 2 and Fig. 1, the order of survival ratio in the species of Japanese origin was from 63% of *R. metternichii* var. *hondoense* f. *brevifolium* through 56% of *R. brachycarpum*, 38% of *R. metternichii*, 33% of *R. metternichii* var. *hondoense*, 29% of *R. metternichii* var. *hondoense* f. *micranthum*, 26% of *R. degronianum*, 18% of *R. yakushimanum*, to 8% of *R. aureum*. Although the two extreme cases, *i. e.*, the highest survival ratio in *R. metternichii* var. *hondoense* f. *brevifolium* and the lowest one in *R. aureum*, were consistent with the previous paper[2], the numerical values in the present experiment were almost exclusively lower than those in the previous one, and in the order of species in survival ratio some discrepancies were also encountered between the two experiments. The cause of these disagreements was probably derived from the difference of seed sources, and that of growing conditions, especially in fertilizer level which was, as mentioned before, much heavier in the present experiment. As seen in Fig. 1, the survival ratios were also different with the difference of habitat at which each seed lot was collected.

The survival ratio of *R. metternichii* might be worthy of mention, because it was only 24% in the previous experiment[2]. Therefore, the increase to 38% was remarkable, considering the much severer growing condition in the present experiment. Evidently, this increase was originated from the high survival ratio, 71%, found in the group of Nishi-sonogi peninsula in Nagasaki Prefecture. It might be of significance to point out that the environmental conditions of Nishi-sonogi peninsula agree well with those of Oki-island, the habitat of *R. metternichii* var. *hondoense* f. *brevifolium*, in the fact that both populations have been isolated geographically from the other

R. pseudochrysanthum (Hehuan-dongfeng)

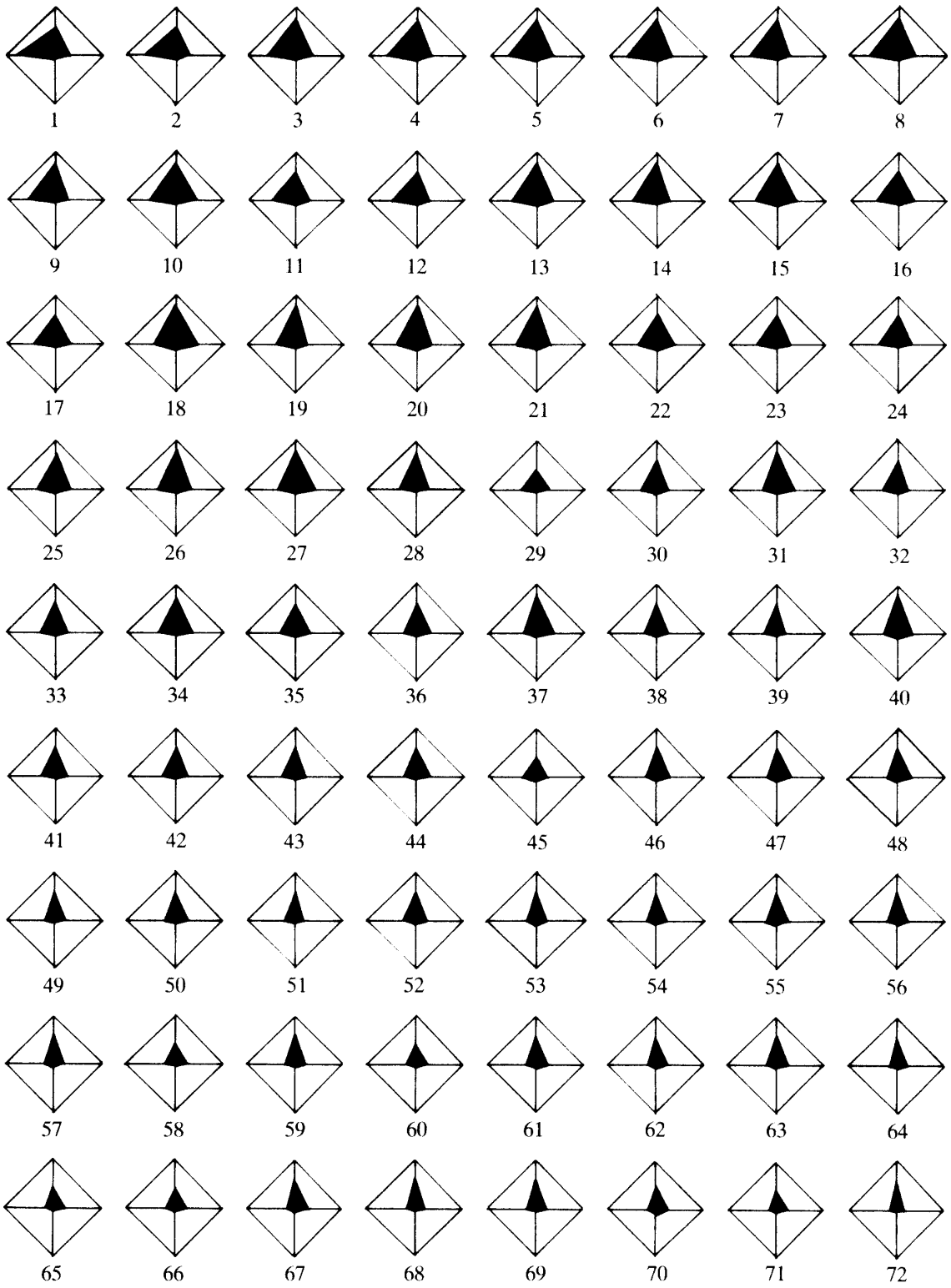
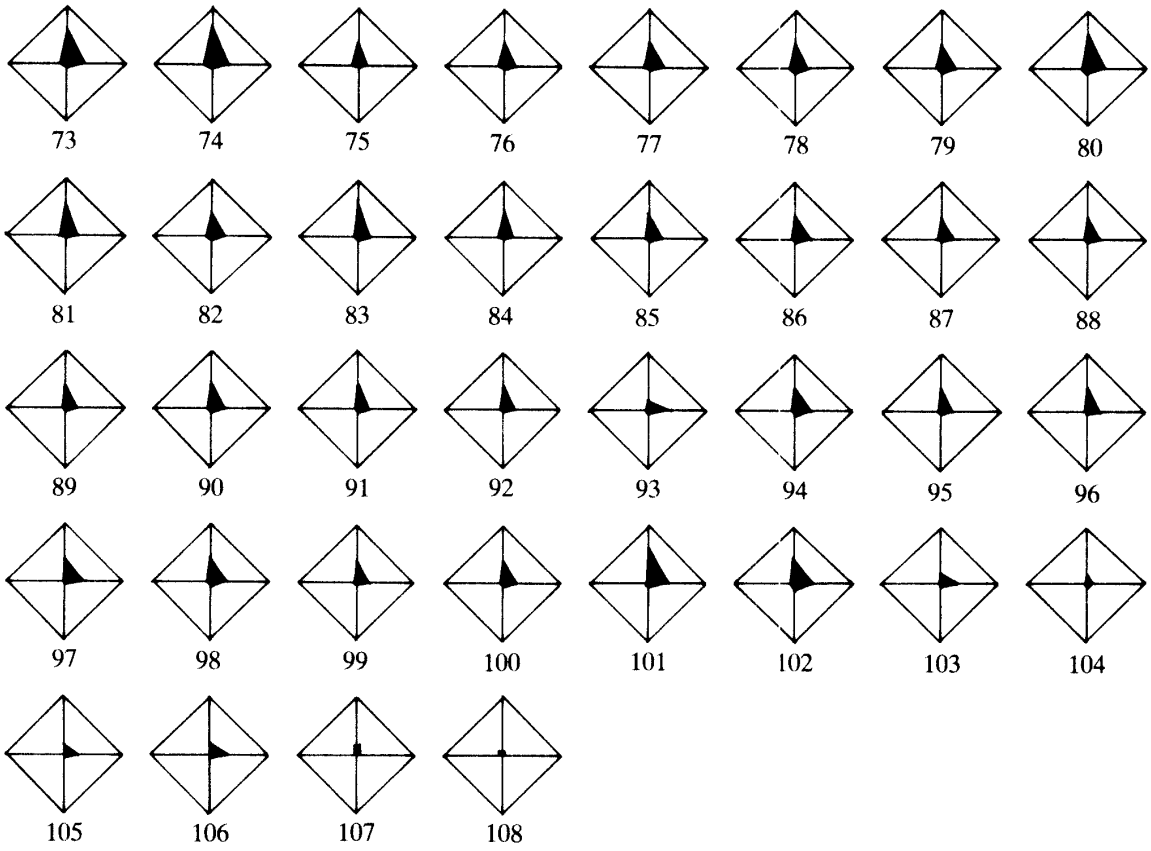
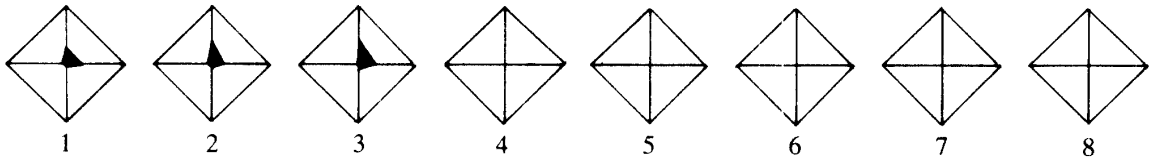


Fig. 1 (1). The survival ratio, vigour and growth of the seedlings in the various species. Each corner of square was survival ratio (left), vigour (top), plant height (right) and leaf size (bottom), respectively.

R. pseudochrysanthum (Hehuan-dongfeng)



R. pseudochrysanthum (Xitou-shan)



R. pseudochrysanthum-R. morii hybrids (Shimen-shan)

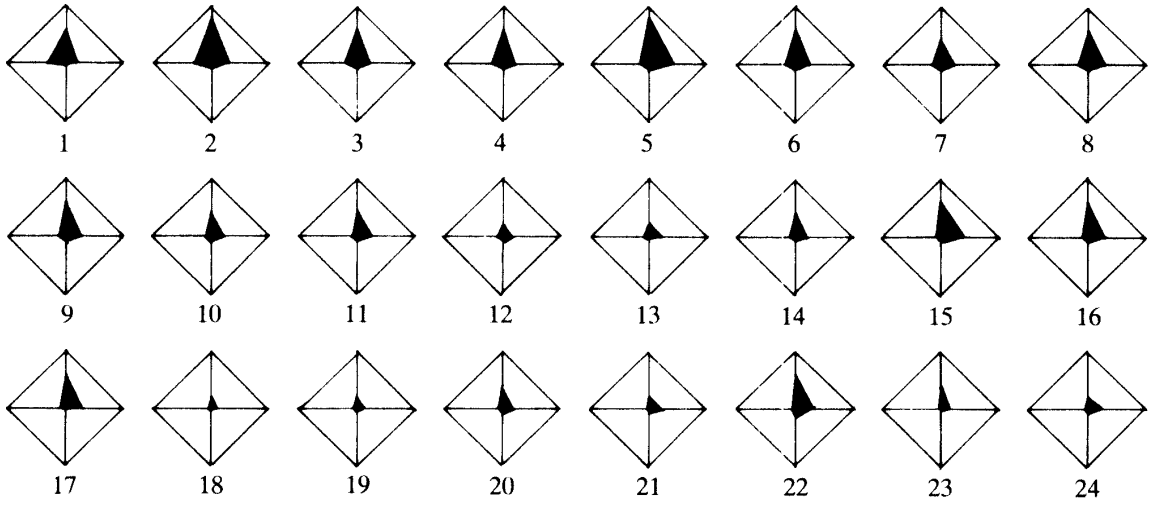
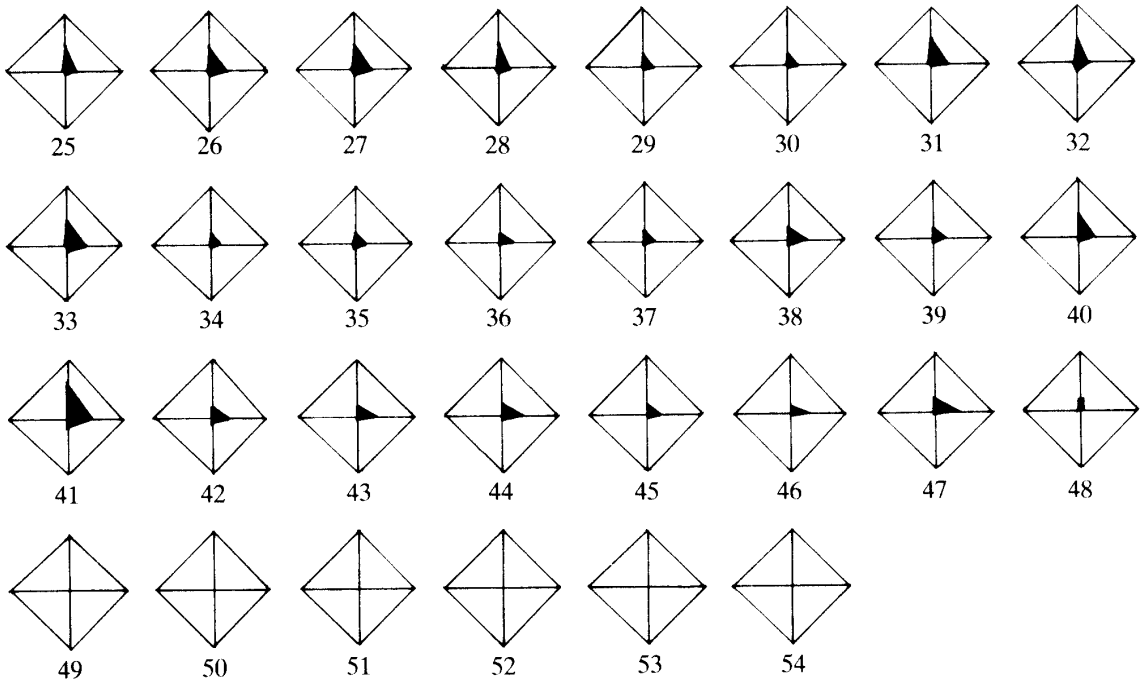
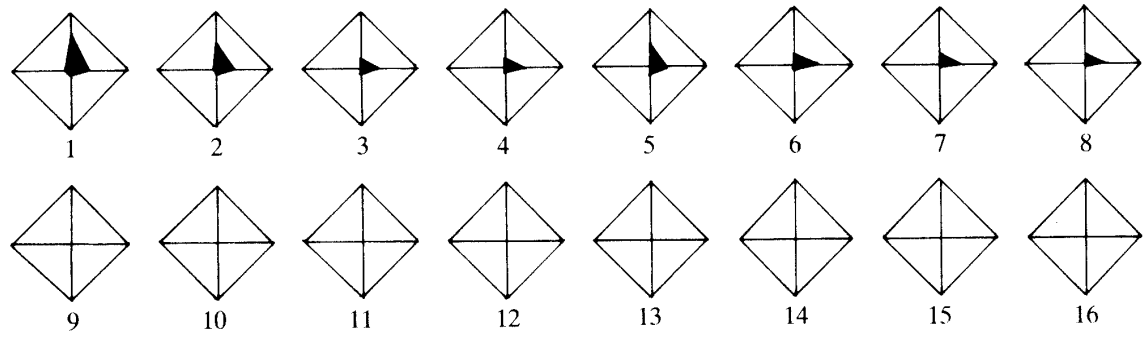


Fig. 1 (2). The survival ratio, vigour and growth of the seedlings in the various species.

R. pseudochrysanthum-R. morii hybrids (Shimen-shan)



R. morii (Survey point E)



R. simiarum (Hong Kong)

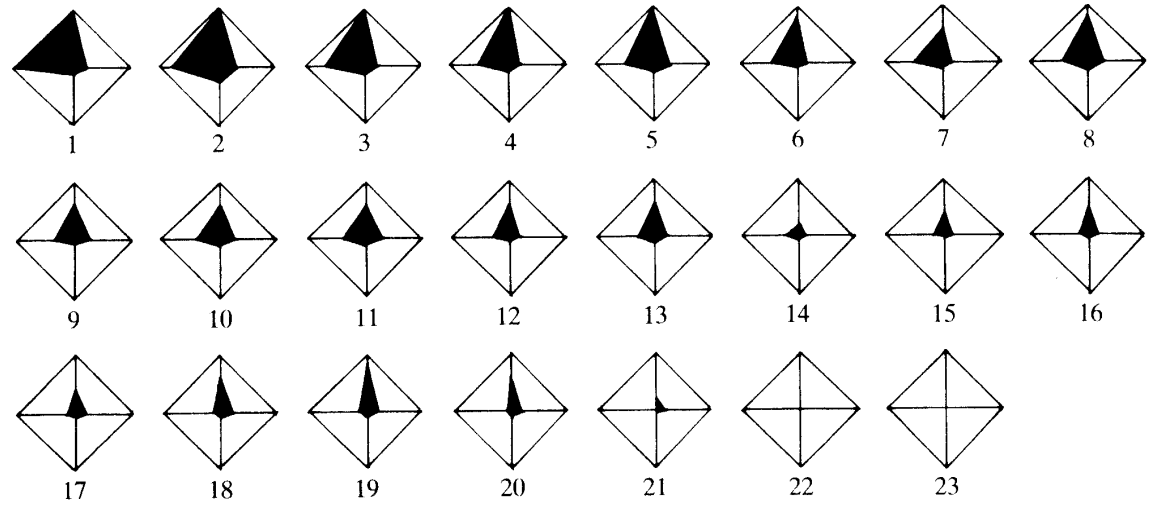


Fig. 1 (3). The survival ratio, vigour and growth of the seedlings in the various species.

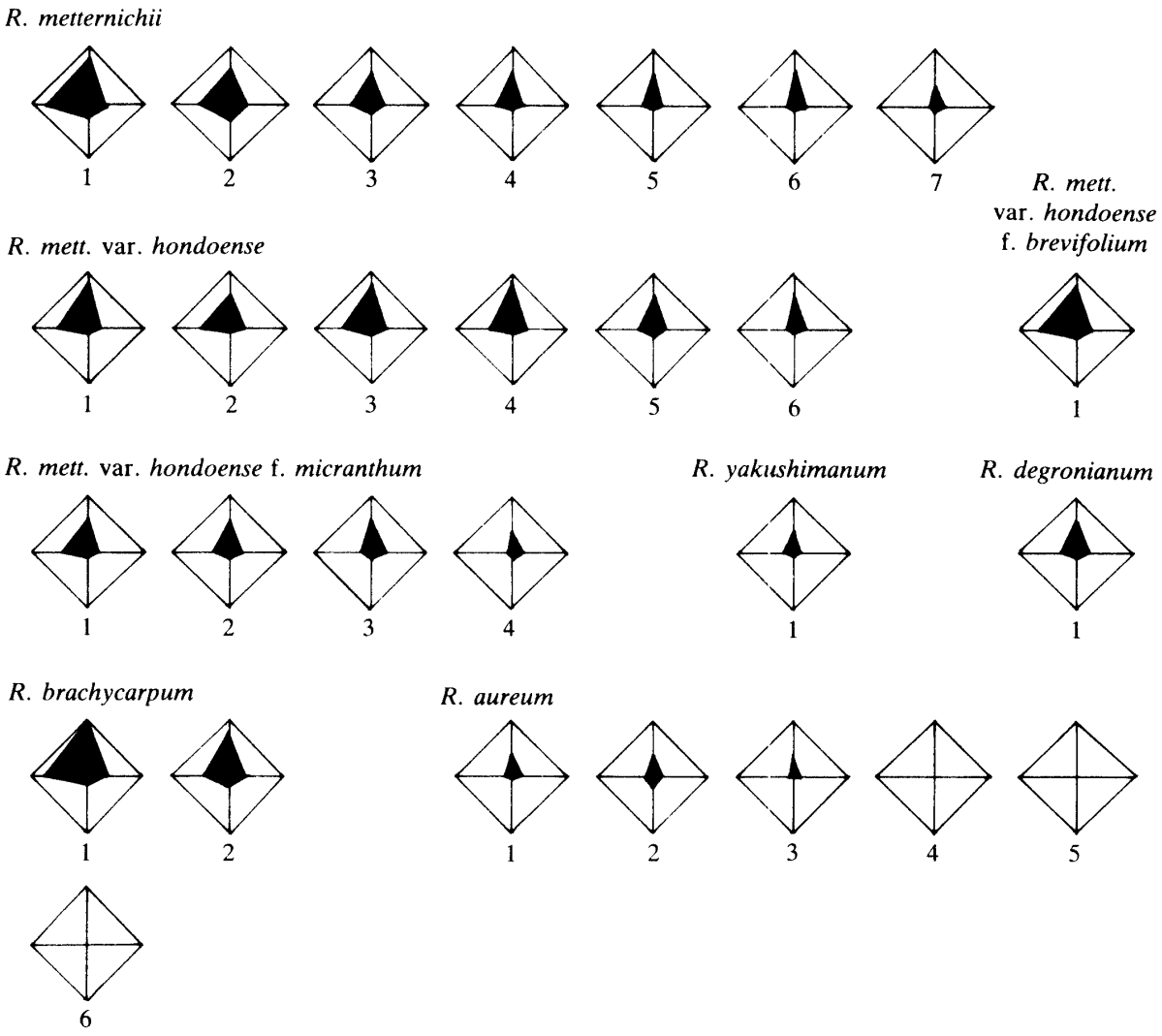


Fig. 1 (4). The survival ratio, vigour and growth of the seedlings in the various species. [*R. metternichii*]: 1. Nishi-sonogi-peninsula, 2. Kujuh-zan, 3. Omae-dake, 4. Syaka-dake, 5. Mimata-yama, 6. Middle point between Omae-dake and Syaka-dake, 7. Mimata-yama. [*R. metternichii* var. *hondoense*]: 1. White flower (garden origin), 2. Oh-dai-ga-hara-san, 3. Dai-hi-zan, 4. Kumao-yama, 5. Kai-gake-kei, 6. Goka-yama. [*R. metternichii* var. *hondoense* f. *brevifolium*]: Doh-go, Oki-island. [*R. metternichii* var. *hondoense* f. *micranthum*]: 1. Dai-nichi-zan, 2. Oh-dai-ga-hara-san, Daija-gura, 3. Dai-hugen-dake, 4. White flower×white flower (garden origin). [*R. yakushimanum*]: Kuromi-dake. [*R. degronianum*]: garden origin. [*R. brachycarpum*]: 1. Hakkohda-san, 2. Erimo-cape. [*R. aureum*]: 1. Yuhbari-dake, 2. Rebun-island, 3. Kita-dake, 4. Kuna-shiri-island, 5. Mokoto-yama, 6. Yoh-tei-zan.

major ones distributed widely in the inland in Kyushu and Honshu and have not been favoured by high mountains to climb up, both of which were presumed in the previous paper[2] to be one of the cues for the acquisition, or the preservation, of heat resistance in rhododendrons.

In the species of Taiwan origin the general survival ratios were much lower than those of Japanese origin. In *R. pseudochrysanthum* the seed lots of Xitou-shan were much inferior to those of Hehuan-dongfeng of Hehuan-shan, suggesting the genetic differences concerning the heat resistance between these two different inhabitants. This might indicate the importance of the careful selection of habitats, along with the case of Japanese origin, to collect the superlative germplasm.

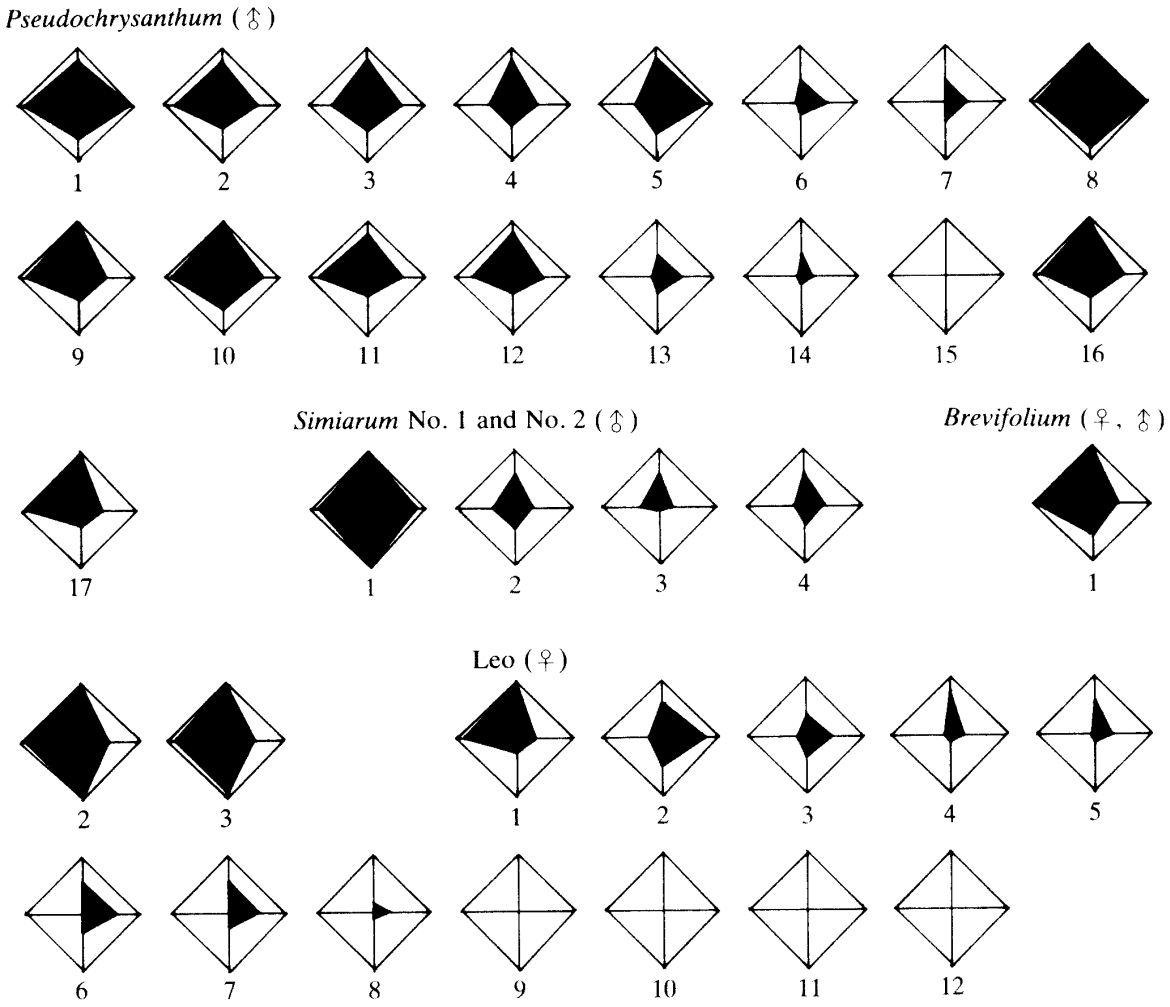


Fig. 2. The survival ratio, vigour and growth of the hybrid seedlings in the representative crosses. [*R. pseudochrysanthum* KHD1 (♂)]: **1.** (President Roosevelt × *R. hyperythrum*) No. 1, **2.** Ditto No. 2, **3.** Ditto No. 3, **4.** Ditto No. 4, **5.** Ditto No. 5, **6.** (*R. aureum* × *R. hyperythrum*), **7.** RM 11. [*R. pseudochrysanthum* KHD2 (♂)]: **8.** *R. formosanum*, **9.** Purple Splendour, **10.** (President Roosevelt × *R. hyperythrum*) No. 6, **11.** Ditto No. 7, **12.** Ditto No. 3, **13.** Scintillation, **14.** Doc, **15.** RM 11. [*R. pseudochrysanthum* KHD3 (♂)]: **16.** (President Roosevelt × *R. hyperythrum*) No. 6, **17.** (*R. metternichii* f. *brevifolium* × Gill's Crimson). [*R. simiarum* No. 1 and No. 2 (♂)]: **1.** (Red No. 1 × Jock), **2.** (*R. yakushimanum* × *R. simiarum*), **3.** Bambi (No. 1), **4.** Ditto (No. 2). [*R. metternichii* f. *brevifolium* (♀ and ♂)]: **1.** *R. pseudochrysanthum* KHD2 (♂), **2.** (President Roosevelt × *R. hyperythrum*) No. 8 (♀), **3.** A. Bedford (♀). [Leo (♀)]: **1.** *R. metternichii* f. *brevifolium*, **2.** *R. aberconwayi*, **3.** Blitz, **4.** (*R. yakushimanum* × Elizabeth) No. 1, **5.** Ditto No. 2, **6.** (Kimberly × *R. aberconwayi*), **7.** *R. pseudochrysanthum* KHD2, **8.** Ditto KHD3, **9.** Streatley, **10.** Flora's Boy, **11.** RM 11, **12.** Koh-gyoku.

Differences in number such as in (President Roosevelt × *R. hyperythrum*) mean different individual.

In the species of Hehuan-shan the survival ratios of *R. morii*, the inhabitant of closed and mild circumstances under the coniferous forest, were much inferior to those of *R. pseudochrysanthum*, the inhabitant of a rocky or stony ground in the widely open sunny places, in spite of the higher altitude of habitat in the latter species[1]. In this context, the survival ratio of the population of Shimen-shan, which was disclosed to be the natural inter-specific hybrids between *R. morii* and *R. pseudochrysanthum* from their various characteristics[1], was intermediate

Table 2. Summarized survival ratio in the various species examined

Species	Survival ratio			
	No. of seedlings survived	Total no. of seedlings examined	No. of plot	Percentage (Range) (%)
R. pseudochrysanthum (Hehuan-dongfeng)	4716	19955	108	23.6 (81.9– 0.5)
R. pseudochrysanthum (Xitou-shan)	6	292	8	2.1 (7.1– 0.0)
R. pseudochrysanthum-R. morii hybrid (Shimen-shan)	590	10028	54	5.9 (28.6– 0.0)
R. morii (survey point E)	32	2911	17	1.1 (7.5– 0.0)
R. simiarum (Hong Kong)	350	1227	23	28.5 (91.3– 0.0)
R. metternichii	561	1478	7	38.0 (71.1– 8.9)
R. mett. var. *hondoense*	260	788	6	33.0 (50.0–16.7)
R. mett. var. *hondoense* f. *brevifolium*	128	203	1	63.1 —
R. mett. var. *hondoense* f. *micranthum*	170	592	4	28.7 (44.8– 5.2)
R. yakushimanum	19	107	1	17.8 —
R. degronianum	30	115	1	26.1 —
R. brachycarpum	242	432	2	56.0 (73.0–40.8)
R. aureum	20	259	6	7.7 (12.2– 0.0)

between these two species. From these findings, it might be concluded that *R. morii* did not preserve, or develop, the heat resistance as in the case of *R. pseudochrysanthum.*

Of particular interest were the survival ratios of *R. pseudochrysanthum* of Hehuan-dongfeng. The average was only 23%, but when compared on the basis of individual seed lot, *i. e.*, the difference of mother plant from which the seeds were collected, a tremendous difference in survival ratio was observed from the highest 82% to the lowest 0.5%, and the number of the seed lots whose survival ratio was higher than 50% was 14 strains, or 13% of the 108 seed lots examined. The similar situations would probably be realized in the other species of Taiwan origin, if the milder experimental condition was employed as compared with the present experiment.

Moreover, almost in parallel with the range of *R. pseudochrysanthum* of Hehuan-dongfeng, that of variation in *R. simiarum* was also remarkable, encompassing from the highest 91% through various intermediates to the lowest 0%, although the mean survival ratio, 29%, was unexpectedly low, considering the low latitude (22°25′ N) and low altitude (460–550 m) of its habitat, together with Wada's declaration[12] on this species to be highly promising for the breeding material to create the heat resistant garden forms.

A tremendous variation in the survival ratio within the population consistently found in *R. pseudochrysanthum* of Hehuan-dongfeng and *R. simiarum* in Ngau-ngak-shan, might again indicate the importance of a careful selection of individual mother plant, in addition to the selection of the habitats before mentioned, to collect and secure the highly valuable germplasms for future breeding.

In comparison with the heat tolerance, in *Rhododendron* much more has been known for the cold tolerance. From a lot of seedlings of *R. fortunei,* Schroeder[11] selected very hardy 15 plants, whose offsprings crossed with other rhododendrons showed a very high survival ratio regardless of the tenderness of the pollen parent. Another typical example was cv. Catalgla, a selected seedling of *R. catawbiense* var. *album,* which has been extensively used for hybridizing along with other

forms, and has transmitted to its offsprings the cold resistance which in the most successful case is described as ironclad hardiness, able to endure −29°C without injury[5]. The variation in hardiness in plant and/or flower buds among cultivars of rhododendrons and azaleas was also widely known[3,4,6-10].

In Fig. 2 the data of the directly related crosses were summarized, which were drawn out from 154 cross combinations conducted in 1985. For getting any clues to the mode of inheritance, the desirable experimental procedure would be the diallele cross, but in the present experiment it was not possible to conduct such a systematic cross. Therefore, it might be dangerous to draw a definite conclusion from these incomplete data. In spite of these limitations, it was evident that the substantial improvement in the survival ratio was possible with the proper selection of cross combinations in the descendants of *R. pseudochrysanthum*.

It was also of consequence that the survival ratios in the crosses of *R. metternichii* var. *hondoense* f. *brevifolium* used as either male or female parent, were consistently high even in a cross with cv. Leo. In spite of its stoutness, Leo afforded almost exclusively the offsprings of low survival ratio. The exact reason was not clear, but this cultivar might contain some latent genetic defect which does not develop phenotypically, but will appear in later generation.

(2) Ornamental value

Although many species dealt in the present paper have beautiful foliage and good growth habit, those of *R. pseudochrysanthum* are excellent[1,3,4]. Its growth habit is usually tight and compact, having short stems densely branched and tiny, thick and rigid leaves inserted upright, a rare characteristic in rhododendrons. *R. simiarum* also has excellent foliage[1,12]; being very thick and very rigid as if sclerophyllous plants, shiny in upper surface, and inserted upright, although the size of leaves is larger than that of *R. pseudochrysanthum*.

As seen in Figs. 1 and 2, however, the leaf size of F_1 seedlings derived from the crosses between *R. pseudochrysanthum* and other rhododendrons was consistently larger than that of *R. pseudochrysanthum*, even in the cross with *R. metternichii* var. *hondoense* f. *brevifolium* with medium sized leaves.

However, the leaf size of young seedlings is affected not only by the plant vigour in each sequential developmental stage, but by the genetic structure which will come to determine the eventual leaf size in the adult plant. Therefore, it might be reasonable to assume that the final leaf size of these hybrids of *R. pseudochrysanthum* would not come to be so big as might be supposed from the present developmental stage, because the growth of seedlings in *ca.* 3/5 of the cross combinations was almost exclusively far more vigorous than that of *R. pseudochrysanthum*.

Together with *R. formosanum*, another species native to Taiwan, *R. pseudochrysanthum* and *R. simiarum* were found to transfer their upright foliage to their descendants, although the data were not presented here. This was another characteristic worthy of mention.

Summary

The survival ratio and the feature of seedling growth of the native species of Taiwan and Hong Kong were examined, along with those of some species of Japanese origin and some of their hybrids, in order to evaluate the value as the gene sources for the future breeding of heat resistant rhododendrons.

In the species of Japanese origin, the survival ratios were noted to be different with the

difference of species and habitat. As in the previous experiment, *R. metternichii* var. *hondoense* f. *brevifolium* again exhibited the highest survival ratio, and the lowest was observed in *R. aureum*. Among *R. metternichii*, the inhabitant of Nishi-sonogi peninsula exhibited the highest survival ratio, the environmental conditions of which agreed well with those of Oki-island, the habitat of forma *brevifolium*.

In the species of Taiwan origin, the general survival ratios were much lower than those of Japanese origin, but here again the difference in survival ratio varying with difference of species and habitat was encountered. Moreover, when compared on the basis of individual seed lot, the difference of mother plant, the tremendous variation in the survival ratio were found to be included. The same situation was also valid in *R. simiarum*, the native of Hong Kong, indicating the importance of the careful selection of mother plant, in addition to the proper selection of habitat, for securing the highly valuable germplasms for future breeding.

In the cross experiment, the substantial improvement in the survival ratio was found to be feasible with the proper selection of cross combinations in the descendants of *R. pseudochrysanthum*. Moreover, *R. metternichii* var. *hondoense* f. *brevifolium* was revealed to be excellent parent for heat resistant rhododendrons. However, some unusual features were also met with in the behaviour of cv. Leo.

Some descriptions were made also on to the aspects of ornamental value, especially in *R. pseudochrysanthum* and *R. simiarum*.

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